
# RAD-AID Global Curriculum for Interventional Radiology

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# Contents

## *Background*

### *Introduction*

Interventional Radiology (IR), originally a subspecialty that evolved from diagnostic radiology has become an established and independent clinical specialty in most of the developed world. IR involves the performance of minimally-invasive diagnostic and therapeutic procedures using image guidance to treat a broad range of diseases and conditions. Instead of direct visualization available to the surgeon performing open surgery, the IR physician uses ultrasound (US), computed tomography (CT), magnetic resonance imaging (MRI) and fluoroscopy for visualization during the procedure. These therapies often have lower complication rates, shorter hospital stays and have overall lower costs than surgical therapies[1]. Access to IR has been recognized by patients and physicians as beneficial and integral to medical care[2].

Undoubtedly, IR adds great value to a wide variety of patient populations in both diagnostic and therapeutic applications. In many developed countries, as in the United States, IR is a recognized specialty with unique training pathways and certifications. As the field continues to grow, novel procedures and treatment combinations are added, with additional development of subspeciality fields including neuro-interventional radiology, pediatric interventional radiology and interventional oncology.

### *Clinical practice and longitudinal care*

Although IR was initially considered a procedural service, it has become clear that in order to ensure the best patient care, IR includes longitudinal care via direct consultation in the inpatient and outpatient setting. Interventional Radiologists are involved in the full spectrum of patient care including clinical assessment, image interpretation, procedural performance, follow-up, and management of complications. In the inpatient setting, the IR physician participates in the patient's care throughout their hospital stay. In the outpatient setting, elective IR procedures are discussed prior to an IR procedure and regular follow-up visits should occur after the intervention. Prior to any procedure in the inpatient and outpatient setting, the IR physician obtains consent after a thorough discussion of potential risks, benefits and alternatives.

The IR physician is an essential member of the treatment team by communicating effectively with patients and referring providers, establishing referral patterns and tailoring treatment approaches for the benefit of the patient. The need for longitudinal involvement by the IR physician becomes crucial in newly established practices where it can be important to recognize and manage potential complications of these procedures.

### *Limitations in low resource settings*

IR is an innovative, high technology and device-driven field, factors which have hindered its early adoption in the resource-limited setting. IR relies heavily on access to specific training and

the availability of certain technology in order to diagnose and treat patients. In addition to availability of imaging modalities including US, CT, MRI and fluoroscopy, the cost of the often disposable tools required for IR procedures can create a financial barrier. An assessment of the cost effectiveness of IR, which compared Canada to the global landscape in 2014, found that Canada lags behind other developed countries in the adoption of patient-friendly, cost saving, and life-saving IR treatment. The authors concluded that this constitutes a problem for the Canadian healthcare system because IR has been shown to reduce patient hospital stays and costs[1].

While establishing IR services initially requires greater investments than surgical fields due to acquisition of imaging facilities and equipment, IR for many indications is more cost effective than open surgery, potentially adding long-term value to any healthcare system. In addition to the initial investments required for acquisition of imaging facilities, ongoing costs associated with their maintenance and the procurement of procedural equipment, establishment of IR services also requires additional staff with investment in specialized training.

Outside the developed world, exposure to IR training is limited. This leads to a lack of patient access to IR physicians in these countries. Hiring and recruiting physicians from abroad may provide immediate solutions if available; however, these strategies may prove unsustainable.

The comprehensive and sustainable solution for establishment of IR services in the low resource setting is the initiation of local training programs. This facilitates training of radiologists, technologists and nurses with in-depth knowledge of the local medical landscape. IR involves diverse therapies developed by experts all over the world. For example, the practice patterns of IR in North America, Europe, or East Asia may be very different from the needs of IR in centres in Central Asia or sub-Saharan Africa. Training platforms can be adapted to the local circumstances, depending on the resources available and identified areas of need. Before offering more involved and complex procedures, these IR services must build a strong foundation of basic procedures that can be applied readily. As an IR service progresses in this low resource setting, regular reassessments allow for flexible adaptation, evaluation and expansion of the curriculum.

## *Purpose*

To provide an educational blueprint for establishing and maintaining a comprehensive Interventional Radiology training program in the developing world. This curriculum focuses on teaching routine and frequently required procedures and allows for supplementation with more complex procedures as the program advances.

## *Clinical teaching and experience recommendations*

### *Curriculum overview*

Most dedicated IR training programs last between 1 and 3 years and can be supplemented with additional IR-subspecialty training. The implementation of this curriculum will vary depending on pre-existing skills and knowledge in the provider institution, the local need for IR, which will determine case-load, as well as local access to imaging facilities and procedural equipment. It is proposed that in most sites, this curriculum would be incorporated into a two year training program. Completion of training would involve the assessment of competence with a formalized national or international IR examination. Structured two year training programs will depend on existing training background and staged introduction to interventional services can be performed via integration into the existing radiology residency experience. The IR situation in the training institution should be assessed prior to the development of a training program, this will allow an understanding of the case-load and case-mix and enable the development of realistic training goals which can be achieved in that centre.

### *Prerequisites*

Entering dedicated IR training requires prior training in diagnostic imaging (typically 3 years) and medicine or surgery (typically 1-2 years). The IR trainee should demonstrate proficiency in performance and interpretation of all available diagnostic modalities including US, MRI, fluoroscopy, CT and nuclear medicine. Knowledge of relevant physiology, pathology and anatomy including anatomic variants is mandatory for safe practice in IR.

### *Clinical Training*

Clinical training in IR involves case-based instruction under the apprenticeship model. The trainee should develop necessary the skills to perform procedures independently. More complex procedures will be mastered with varying levels of competence, depending on exposure during training and likely future practice. Different sites may offer varying degrees of exposure to certain modalities or procedures and trainees may progress at different rates to achieve similar levels of competence by the end of their training. Rather than mandating each trainee to obtain exposure and gain competence in the full range of modalities and procedures in the field of IR, each training site should focus on teaching core skills and techniques based on the local resources and need. In addition to procedural skills, the trainee should have exposure to the full range of pre- and post-procedural patient care including outpatient clinics, inpatient consultations, on-call work, ward rounds, follow-up, management of complications, multidisciplinary conferences, and morbidity and mortality conferences.

IR education should be delivered in line with the apprenticeship model and supplemented as follows:

- Formal teaching.
    - This includes in person teaching in the form of lectures, seminars, journal clubs, participation at national and international meetings, courses, and workshops with a focus on IR. The curriculum can be augmented with the use of web-based learning via participation in online lectures and courses (including those provided by RadAid chapters and possibly those provided by the Resident Fellow Student Council of the Society for Interventional Radiology: www.rfs.sirweb.org).
    - Where expertise in certain IR procedures is not available at a local level, it may be possible to stream lectures from participating US sites

- Self-directed learning
    - Review of IR publications including textbooks, scientific journals, as well as utilization of web-based reading material and online question banks. Maintenance of a case logbook and portfolio to document experience and progress throughout training is a key responsibility of each trainee. This portfolio should include cases, complications and clinical experience, including inpatient and outpatient consultations.

- Training models and simulators
    - Novel model-based simulators allow trainees to learn common procedures and gain confidence without putting patients at risk, especially early in the training pathway. Such models and simulations can be very simple and affordable, such as ultrasound-biopsy models made of locally available materials, but are also low fidelity. In addition to model-based simulators, development of computer-based simulators has the potential to provide more sophisticated training scenarios and change IR training around the world, a high-fidelity training technique. As newer technologies become readily available, including virtual-reality and augmented reality devices, training in the low resource setting may evolve. Additionally, smartphone based applications have the potential for greater trainee access and significant impact on education.

- Research
    - Involvement in preparation and submission of scientific manuscripts to journals and abstracts for presentation at local, regional, national and international meetings should remain a key component during training. New procedural approaches of IR in the low resource setting, quality improvement initiatives and case series will provide ample opportunity for trainees to contribute to the IR community. Participation at international conferences provides a great platform to network and gain exposure to practice in different parts of the world.

- Exchange programs

    - Partnerships between established programs and those in the initiation process can help improve learning and growth. International electives and observerships can provide an opportunity to understand how well established IR departments function; however, they may not involve direct procedural performance. By participating in interdisciplinary conferences, outpatient clinics, ward rounds, consults, and observing a broad range of IR procedures, the visiting trainee will gain better understanding of the full complement of IR and be able to apply this knowledge to their home program.

- Competency levels
    - The following competency levels provide a guide for self-assessment and formal assessment during training. The three main categories to assess competency are knowledge, clinical skills, and technical skills.
        - **Continuous assessment** via feedback sessions and review of logbooks
        - **Structured assessment** can include simulation based assessments; direct observation of practice and procedures; review of cases, outcomes and complications and case-based discussions.
        - **Formal examination** written, oral or computer-based at the national and/or international level. If governing boards have not instituted national certification examinations in subspecialties, thesis development and defense can be substituted within the final year.

- Continuing education
    - Continued learning and monitoring of performance after completion of training is essential in IR practice. Participation in registries, clinical research, teaching and conferences is encouraged.

*Training platforms and certification recommendations*

- Comprehensive approach based on available local resources and expertise supplemented by collaboration with other established institutions
- Essential knowledge and skills include but are not limited to:
    - Understanding of disease processes, anatomy and radiological and clinical findings relevant to IR
    - Appropriate case selection
    - Patient safety
    - Operator safety
    - Attention to sterile technique and the maintenance of good operating practice
- Training certification should encompass a set of basic procedures supplemented by a subset of complex procedures

- Suggested primary platform(s)
    - Non-procedural skills (Radiation safety, pharmacology, image interpretation, professionalism, safety, communication and teamworking, quality improvement)
    - Competency in all core procedures and complex procedures as appropriate to local need

| | |
|---|---|
| Core | Percutaneous biopsy, Drainage/aspiration, Cholecystostomy, PTC/biliary drainage/exchange, Nephrostomy/Nephroureteral stent, Gastrostomy/Gastrojejunostomy, Lumbar puncture, Central venous access, IVC filter placement/retrieval, Pelvic trauma embolization, Splenic artery trauma embolization |
| Advanced | Catheter angiography / angioplasty; percutaneous ablation, pleurodesis, Chemoembolization, Venous ablation, Thrombolysis/Thrombectomy |

### *The interventional radiology multidisciplinary team*

Clinical care in interventional radiology is delivered as part of a wider multi-disciplinary team. Appropriate referral links should exist within the healthcare facility to enable referral of patients for IR procedures and to other specialties as appropriate.

Performance of IR procedures is in conjunction with the multi-professional IR team including nurses, radiation technologists, IR attendings and trainees. The specific roles of the nurses and technologists may vary between healthcare systems and countries however, training of an adequate and appropriate standard should be provided to all staff participating in IR procedures. There should also be a program of continuing professional development for all IR staff.

### *Non-procedural skills*

- Care of the interventional radiology patient. Comprehensive clinical care of the patient requiring interventional radiology procedures should be integrated into the hospital infrastructure. This includes facilities to assess, examine and consent the patient prior to the procedure and the ability to review patients at an appropriate time interval following the procedure. In most institutions this will be achieved by the presence of an IR clinic and performance of ward rounds by the IR team.

- Surgical technique. Careful attention to handwashing, sterility and the maintenance of a surgical field should be observed. Surgical gowns and gloves should be used where appropriate. Doctors performing IR procedures should pay careful attention to the use of sterile drapes to create an appropriate surgical field. Where the IR in training does not already possess these skills (for example from prior surgical training), they should be incorporated into the training program from the outset.
- Radiation Safety in IR. Occupational exposure in IR poses a significant risk to the operators and the staff, which can be reduced by technical, physical and behavioral factors. Careful attention should be paid to limiting exposure time, increasing distance of staff from radiation where practical and use of radiation shielding. IRs should be aware of ways to limit unnecessary exposure and optimization of the radiation dose to the task at hand. Radiation shielding should include the use of lead gowns and thyroid shields, which should be screened for defects at regular intervals. Fixed shielding should be installed and used where practical. Lead glasses are recommended to reduce eye dose. Dose monitoring and practice audit should be performed at regular intervals. IRs should be aware of physical and behavioral strategies to ensure their radiation exposure is as low as possible. More information on occupational radiation exposure in IRs can be found here: https://www.ncbi.nlm.nih.gov/pubmed/20430294. In addition, patient safety must also be considered. More information on patient safety can be found here: https://www.ncbi.nlm.nih.gov/pubmed/19560006 Consideration should be given to the additional radiation protection needs of pregnant staff, including appropriate advice, abdomen dose monitoring and additional abdominal protection. Further information on radiation safety in pregnancy can be found here: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3835582/
- WHO Safe surgery checklist. The WHO has provided a safe surgery checklist, the use of which has been shown to improve outcomes and is associated with a reduced risk of major complications [3]. This can be adapted to the IR environment and its use is encouraged.
- Case recording and follow-up. IR trainees should keep a logbook of cases and procedural outcomes. We recommend a web-based format for case recording and follow-up. Follow-up should be performed at appropriate intervals after the procedure and may occur by phone, internet or text message in accordance with local practice and policies. Procedures should be in place for the ongoing management and follow-up of patients who have IR-inserted indwelling catheters (drainage tubes including nephrostomies, vascular access) including a plan for catheter removal, replacement or definitive management of the underlying condition as clinically appropriate.
- Pharmacology in IR. IR trainees should be familiar with drugs commonly used during procedures and those which effects may affect procedure outcome. These will include, but are not limited to, analgesics; local anesthetic agents; sedatives; intraprocedural anticoagulants; vasodilators; anti-fibrinolytics. Reversal agents for the commonly used sedative drugs should be readily available and all IR physicians must have a working

knowledge of their application and use. Safe sedation practice should be followed where sedation is used.

- Coagulation. IR procedures carry a risk of bleeding. Any extra risks should be mitigated to reduce the incidence of bleeding complications. This may include with-holding anticoagulant or antiplatelet medications prior to the procedure, waiting until any reversible coagulopathy has corrected or substituting an alternative procedure. Guidance on coagulation in IR can be found here: https://www.jvir.org/article/S1051-0443(12)00297-7/pdf

  https://www.jvir.org/article/S1051-0443(12)01238-9/pdf

- Antibiotics. Many IR procedures carry a risk of bacterial translocation into the bloodstream which may result in a bacteremia and ultimately the development of sepsis. IR practitioners should be aware of these risks, how to mitigate them and appropriate use of antibiotic prophylaxis. Guidance on antibiotic coverage in IR can be found here: https://www.jvir.org/article/S1051-0443(18)31259-4/fulltext
- Analgesia and sedation. Local anesthesia is almost always required in interventional radiology. IRs and trainees should be familiar with the drugs they use, safe administration and the identification and treatment of any toxic effects. In some procedures in some settings sedation may be appropriate where this can be offered safely. Some guidelines on anesthesia and sedation can be found here: http://pubs.rsna.org/doi/full/10.1148/rg.332125012 Arrangements should be made for post-procedure analgesia by the responsible IR physician, these requirements will vary between patients, procedure and the healthcare institution.

- Imaging equipment. IR trainees should be familiar with the practice of all imaging modalities used to perform IR procedures including limitations, use and basic settings. Meticulous attention should be paid to gaining good ultrasound technique, with good scan technique, image optimization and continuous needle visualization. The IR should have a good understanding of the use of the fluoroscopy equipment including image optimization and the use of the ALARA principle in dose reduction. CT guided procedures require a different skill set and these should be taught separately. MR-guided interventional skills may be required if the equipment is locally available.

- Equipment. IR procedures should only be performed by practitioners specifically trained to perform that procedure, or under the close supervision of such practitioners, using equipment (including imaging equipment) with which they have had appropriate training and are familiar. Before performing any procedure, IRs should ensure that the all equipment necessary for the procedure and that required to treat any frequently-occurring or serious complication is available and in working order. This includes a functioning imaging system with staff appropriately trained in its use, equipment for monitoring the sedated patient and the necessary consumables. For sustained functionality, an IR service should have a robust method for the purchase and

procurement of consumable/single-use equipment. Further guidance on the development of a supply chain and some available suppliers will be made available from RadAid when available. A robust system of supply and procurement is mandatory to sustain an IR service and the functionality of that service as a training department.

- Consent. Patients should be provided with and be able to retain information regarding the procedure including why it is necessary, alternative procedures (including not having any procedure) and the likely consequences. They should understand the risks of the procedure as relevant to themselves and their situation. The local formal consent process should be followed, as relevant to surgical procedures.

- Communication and teamworking. The IR trainee must demonstrate the ability to communicate effectively with patients and their families and other members of the healthcare team. This includes effective multidisciplinary team working and also during the handover of patients to other clinical teams. Specific roles of the nursing and technologist staff will vary between sites and healthcare systems but will include pre-procedural preparation, sedation and patient monitoring, participation in room set-up, operation of the equipment, radiation protection and aftercare of the patient.

*Procedures – Contents*

## Section A – Core procedures



## Section B – Complex procedures

6.1.3 Prostate artery embolization
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6.3 Thoracic aortic stenting for BTAI
6.4 Thrombolysis/thrombectomy
6.5 Peripheral arterial intervention
6.6 Venography/venoplasty/stenting
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6.10 Carotid artery stenting
6.11 TIPS/TIPS revision/DIPS
6.12 BRTO/PARTO/CARTO
6.13 Complex IVC filter retrieval

## *Core procedures*

| ***1.1 US guided FNA – superficial (thyroid, superficial LN)*** | |
|---|---|
| Indications | • Obtain tissue for microbiological or pathological diagnosis |
| Contraindications | • Absolute – no safe access to lesion<br>• Relative – coagulopathy (see introduction) |
| Procedure specific risks | • Bleeding; infection; non-diagnostic sample; nerve damage |
| Equipment | • Ultrasound (linear probe); skin prep; sterile probe cover; LA; 25g needles; core needle biopsy kit; sample pot; specimen form; sterile skin dressing. |
| Aftercare | • Observe for short period of time prior to discharge |
| Special considerations | • How to send sample (discuss with local lab – often formalin if pathology; saline if microbiology for culture; solid organ biopsies sometimes sent in MTM fixative; FNA samples may be sent in fixative e.g. CytoRich Red |
| Modifications | |
| References | https://link.springer.com/article/10.1007%2Fs00270-017-1658-5 |

| **1.2 US guided core biopsy – solid organ** |
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| Indications | • Obtain tissue for microbiological or pathological diagnosis to guide treatment. Biopsy may be for diffuse pathology or targeted (eg to focal lesion within the liver) |
| Contraindications | • Absolute – no safe access to lesion<br>• Relative – coagulopathy (see introduction) |
| Procedure specific risks | • Bleeding; infection; non-diagnostic sample; nerve damage, damage to adjacent structures. Organ-specific risks vary with organ (eg. Liver biopsy comes with a risk of bile leak) |
| Equipment | • Ultrasound (usually curvilinear low frequency probe); skip prep; sterile probe cover; LA; core needle biopsy kit; sample container; specimen form; sterile skin dressing. |
| Aftercare | • Patients rest in bed for 2 hours post procedure to reduce the risk of bleeding. Respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected. |
| Special considerations | • Liver biopsy in the presence of bile duct dilatation is more likely to result in bile leak and careful consideration should be given to performing biopsy in this case.<br>• Abdominal ascites may also increase the risk of bleeding complication and if liver biopsy is necessary this could be drained first to allow safe access.<br>• A continued bleed and instability may require angiography with possible embolization.<br>• How to send sample (discuss with local lab – usually formalin if pathology; saline if microbiology for culture) |
| Modifications | |

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| References | https://link.springer.com/article/10.1007%2Fs00270-017-1658-5 |

| **1.3 Image-guided Lumbar Puncture (LP)** | |
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| Indications | ● Laboratory analysis of cerebrospinal fluid (CSF)<br>● Assessment of CSF pressure<br>● Access for intrathecal chemotherapy infusion<br>● Injection of contrast material for CT myelography |
| Indications for image-guided LP | ● Failed bedside attempt<br>● Bedside attempt unlikely to be successful (eg. patient positioning; spinal deformity; scarring) |
| Absolute Contraindications | ● Uncorrected coagulopathy or anticoagulation<br>● Elevated intracranial pressure<br>● Clinical findings suggestive of CSF flow obstruction<br>● Low-lying conus, tethered cord and myelomeningocele |
| Relative Contraindications | ● Medical instability<br>● Infection<br>● Pregnancy<br>● Contrast allergy (for myelography)<br>● Elevated intracranial pressure |
| Procedure specific risks | ● Cerebral herniation<br>● Cord compression secondary to hemorrhage into epidural or subarachnoid space<br>● Nerve injury<br>● Infection and meningitis<br>● Headache<br>● Epidermoid tumor of thecal sac |
| Equipment | ● Standard or biplane fluoroscopy<br>● Basic pack<br>● Local anesthesia<br>● Spinal needle: typically 20g or 22g of appropriate length<br>● Collecting vials for CSF samples |

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| | • Contrast (for myelography)<br>• Sterile skin dressing |
| Aftercare | • 1h bed rest (flat)<br>• No strenuous activity for 24 hours<br>• Hydration to prevent headache |
| Special considerations | • Review of pre-procedure imaging if available to assess level of conus<br>• Always advance or withdraw needle with stylet in place<br>• If post-procedural hemorrhage is suspected due to abnormal clinical findings, assessment for hematoma with MRI or myelography can be performed<br>• Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients, especially in children and pregnant women. |
| Modifications | • Three standard approaches can be considered: Prone midline, prone oblique and lateral |
| References | • https://www.ajronline.org/doi/full/10.2214/AJR.14.14028<br>• https://www.acr.org/-/media/ACR/Files/Practice-Parameters/Myelog-Cisternog.pdf |

| 1.4 Percutaneous image guided drainage | |
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| Indications | • Alleviate pain/discomfort related to collection, treat infection or for sampling of infected material to direct antibiotic therapy |
| Contraindications | • Absolute - no safe access to lesion<br>• Relative – coagulopathy (target INR <1.5; Plt >50,000) |

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| Procedure specific risks | ● Damage to adjacent structures depending on route used: pneumothorax; bowel perforation; biliary injury; bleeding; infection |
| Alternative Interventions | ● Surgical washout<br>● Conservative management |
| Technique | ● US guided, Fluoroscopy guided, US/fluoroscopy guided, CT guided<br>● SELDINGER: access to collection with dilation and insertion of drainage tube over the wire<br>● TROCAR (direct): Insertion of drainage tube in single pass |
| Equipment | ● Imaging: Ultrasound, fluoroscopy, and/or CT<br>● Basic pack<br>● Medications: IV analgesics, local anesthesia<br>● Sample pot / specimen form for microbiology<br>● Access needle (22g-18g)<br>● Guidewire<br>● Dilatators (for Seldinger technique)<br>● Drainage tube (6F-12F size; pigtail, cope loop, accordion)<br>● Closure: Suture/drain-fix dressing, sterile skin dressing<br>● Optional: abscessogram |
| Aftercare | ● Patients rest in bed for 2 hours post procedure to reduce the risk of bleeding. Respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected<br>● Stitches should be removed at an agreed interval<br>● Twice daily tube drain rinse with 10 mL of normal saline<br>● Longer-term plan for drain removal or routine change should be agreed with the referring clinical team (usually when output lesse than 30 cc over two consecutive days) |

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| Special considerations | • Tube placement can be confirmed with the instillation of contrast. Fistulas can be identified with abscessogram.<br>• Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients, especially in children and pregnant women.<br>• Locking or non-locking drains may be used. Non-locking drains, where used, should be sutured in place to avoid inadvertent removal. |
| References | • Kandarpa, Krishna, et al. Handbook of Interventional Radiologic Procedures, Wolters Kluwer Health, 2016. ProQuest Ebook Central, https://ebookcentral-proquest-com.eresources.mssm.edu/lib/icahn-mssm/detail.action?docID=4931416.<br>• https://www.acr.org/-/media/ACR/Files/Practice-Parameters/PDFAC.pdf |

| ***1.4.1 Percutaneous drain exchange*** | |
|---|---|
| Indications | • Replacement of existing percutaneous drain |
| Procedure specific risks | • This is a low-risk procedure is done correctly, owing the drain track already being established. In friable tissue eg pancreatitis there is an increased risk of bleeding and infection. |
| Technique | • US guided, Fluoroscopy guided, US/fluoroscopy guided, CT guided<br>• Wire access to collection via existing drain, drain tube is removed over guidewire and replaced with a new one. |
| Equipment | • Imaging: Ultrasound, fluoroscopy, and/or CT<br>• Basic pack<br>• Medications: IV analgesics, local anesthesia usually not required<br>• Guidewire<br>• Appropriate drainage tube<br>• Closure: Suture/drain-fix dressing, sterile skin dressing if appropriate |

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| Aftercare | ● Plan for drain removal or routine change should be agreed with the referring clinical team<br>● Consideration of definitive management of underlying condition |
| Special considerations | ● Tube placement can be confirmed with the instillation of contrast.<br>● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients, especially in children and pregnant women.<br>● Locking or non-locking drains may be used. Non-locking drains, where used, should be sutured in place to avoid inadvertent removal. Their use and removal procedure should be clearly documented to aid clinical team at the time of removal. |

| **1.5 Percutaneous image guided aspiration** | |
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| Indications | ● Alleviate pain/discomfort related to collection, treat infection or for sampling of infected material to direct antibiotic therapy |
| Contraindications | ● Absolute - no safe access to lesion<br>● Relative – Coagulopathy (target INR <2; Plt >25,000) |
| Procedure specific risks | ● Damage to adjacent structures depending on route used: pneumothorax; bowel perforation; biliary injury; bleeding; infection |
| Alternative Interventions | ● Surgical washout<br>● Conservative management |
| Technique | ● US guided, Fluoroscopy guided, US/fluoroscopy guided, CT guided<br>● Yueh or sheathed needle versus thin wall needle |

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| Equipment | ● Imaging: Ultrasound, fluoroscopy, and/or CT<br>● Basic pack<br>● Medications: local anesthesia<br>● Sample pot / specimen form for microbiology<br>● Access needle (22g-18g)<br>● Syringes |
| Aftercare | ● Respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected.<br>● Clean dressings changes as needed |
| Special considerations | ● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients, especially in children and pregnant women. |
| References | ● https://www.acr.org/-/media/ACR/Files/Practice-Parameters/PDFAC.pdf |

| 2.1 Peripherally Inserted Central Catheter | |
|---|---|
| Indications | ● Central venous line for medications, IV infusion or venous sampling - likely duration 7 days to 3 months |
| Contraindications | ● Relative - patients with CKD and potential plan for AV fistula; coagulopathy, infection |
| Procedure specific risks | ● Bleeding, hematoma<br>● Infection<br>● Venous thrombus<br>● Migration or occlusion of PICC |

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| | • Injury to vasculature |
| Alternative Interventions | • SC or IJ CVC, midlines, PIV |
| Equipment | • Basic pack<br>• Vascular access equipment including tourniquet<br>• PICC line kit<br>• Closure: sterile skin dressing |
| Aftercare | • Saline flush |
| Special considerations | • Nondominant arm preferred. Basilic vein typically chosen. |
| References | • Kandarpa, Krishna, et al. Handbook of Interventional Radiologic Procedures, Wolters Kluwer Health, 2016. ProQuest Ebook Central, https://ebookcentral-proquest-com.eresources.mssm.edu/lib/icahn-mssm/detail.action?docID=4931416. |

| **2.1.1 Non-tunneled Central Venous Catheter** | |
|---|---|
| Indications | • Central venous line for medications, IV infusion or venous sampling - likely duration less than 7-14 days<br>• Temporary dialysis or apheresis |
| Contraindications | • Relative - coagulopathy (target INR <2; Plt >25,000) |
| Procedure specific risks | • Bleeding, hematoma<br>• Infection<br>• Venous thrombus<br>• Injury to vasculature |

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| Alternative Interventions | • Peripheral venous access |
| Equipment | • Basic pack<br>• Vascular access equipment<br>• Non-tunneled catheter kit<br>• Closure: sterile skin dressing |
| Aftercare | • Saline flush |
| Special considerations | • IJ access preferred. Subclavian and femoral can be considered for alternative access. |
| References | • https://link.springer.com/chapter/10.1007/978-3-319-40845-3_85 |

| **2.1.2 Tunneled Central Venous Catheter** | |
|---|---|
| Indications | • Central venous line for medications, IV infusion or venous sampling - duration greater than 30 days<br>• Long term dialysis or apheresis |
| Contraindications | • Relative - coagulopathy (target INR <1.5; Plt >50,000), central venous occlusion |
| Procedure specific risks | • Bleeding, hematoma<br>• Infection<br>• Venous thrombus<br>• Injury to vasculature |

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| Alternative Interventions | • Non-tunneled central venous catheter |
| Equipment | • Basic pack<br>• Vascular access equipment<br>• Tunneled catheter kit<br>• Closure: sterile skin dressing |
| Aftercare | • Saline or heparin flush |
| Special considerations | • IJ access preferred. Subclavian, femoral, transhepatic and translumbar routes can be considered for alternative access. |
| References | • https://link.springer.com/chapter/10.1007/978-3-319-40845-3_87 |

| **2.2 Inferior Vena Cava (IVC) Filter Placement** | |
|---|---|
| Indications | ● Thromboembolic disease:<br>○ Known pulmonary embolism (PE) or deep venous thrombosis (DVT) ***and*** failure, complication or contraindication of/to anticoagulation<br>● Prophylaxis<br>○ Head/spine injury, pelvic/long bone fracture, intra-abdominal compression of IVC |
| Relative Contraindications | ● Uncorrectable severe coagulopathy<br>● Bacteremia/untreated infection |
| Procedure specific risks | ● Filter fracture or migration<br>● IVC occlusion<br>● Deployment outside target area<br>● Bleeding, infection, and damage to adjacent structures such as nerves, arteries or veins<br>● Risks of sedation/anesthesia |

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| Equipment | • Equipment for venous access<br>• Lidocaine<br>• Contrast<br>• Deployable IVC filter<br>• Sterile skin dressing |
| Aftercare | • Bed rest and observation in immediate post-procedural period, with monitoring of respiratory rate, heart rate and blood pressure, typically going home in <3 hours<br>• Clinical reassessment for appropriateness and timing of filter removal during first 3 months |
| Special considerations | • Venous access options: Internal jugular veins or common femoral veins - dependent on filter type<br>• Cavogram utilized to assess the following before deployment:<br>  ○ Thrombus presence in IVC<br>  ○ Caval diameter (typically <30mm)<br>  ○ Number and position of renal veins<br>  ○ Presence of anatomic variant (eg duplicate IVC)<br>• Fluoroscopy (dose, field size and fluoroscopy time) should be kept to a minimum in all patients, especially in children and pregnant women. |
| Modifications | • Suprarenal filter placement may be indicated for the following:<br>  ○ IVC thrombus precluding infrarenal placement or thrombus extension above previously-placed filter<br>  ○ Pregnancy<br>  ○ Gonadal vein thrombosis<br>  ○ Duplication/short length of infrarenal IVC<br>  ○ Extrinsic compression/intrinsic narrowing of infrarenal IVC<br>  ○ Need for intraoperative IVC mobilization<br>• Infrarenal IVC diameter between 30-40mm may require Bird's Nest filter, and >40mm may require bilateral iliac vein filters<br>• Duplicate IVC may necessitate dual filter insertion |
| References | • https://www.acr.org/-/media/ACR/Files/Practice-Parameters/ivc-fliterplacement.pdf?la=en<br>• https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3036384/pdf/sir23357.pdf |

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| **2.3 Inferior vena cava filter retrieval** |

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| Indications | ● Patient no longer at risk for PE / full anticoagulation possible<br>● Treat symptomatic IVC filter stenosis/thrombosis/penetration |
| Contraindications | ● Absolute – residual embolus within filter<br>● Relative – Coagulopathy (target INR <1.5; Plt >50,000) |
| Procedure specific risks | ● Injury (e.g. artery, IVC, nerve, viscera)<br>● Hematoma<br>● Infection |
| Alternative Interventions | ● Various techniques including dual IVC/CFV access; filter mobilisation; endovascular forceps or lasers for complicated cases - see further reading<br>● Leaving the IVC filter in place |
| Equipment | ● Basic pack<br>● Vascular access equipment including local anesthesia<br>● Sheath/catheter to perform cavogram<br>● Filter retrieval kit<br>● Closure: sterile skin dressing |
| Aftercare | ● Patients rest in bed for 2 hours post procedure to reduce the risk of bleeding.<br>● Respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected |
| Special considerations | ● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients, especially in children and pregnant women. |
| References | ● Kuyumcu, Gokhan, and T. Gregory Walker. "Inferior vena cava filter retrievals, standard and novel techniques." *Cardiovascular diagnosis and therapy* 6.6 (2016): 642. |

## 3.1 Percutaneous Nephrostomy Insertion

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| Indications | ● Relief of renal obstruction causing urosepsis and/or renal failure<br>● Intractable pain<br>● Urinary diversion<br>● Diagnostic procedure<br>● Access for endourologic procedure (PCNL) |
| Contraindications | ● Absolute – no safe access to kidney<br>● Relative – coagulopathy (see introduction); extreme hyperkalemia (should be controlled first); hypotension; terminal illness with imminent death |
| Procedure specific risks | ● Bleeding<br>● Infection<br>● Nerve damage<br>● Damage to adjacent structures |
| Equipment | ● Ultrasound (usually curvilinear low frequency probe)<br>● Skin prep<br>● Sterile probe cover<br>● LA and access needle<br>● Guidewire<br>● Nephrostomy tube<br>● Suture or drain-fix dressing<br>● Sample pot / specimen form<br>● Sterile skin dressing |
| Aftercare | ● Patients rest in bed for 2 hours post procedure to reduce the risk of bleeding. Respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected<br>● Stitches should be removed at an agreed interval, if appropriate and depending on local practice<br>● Longer-term plan for drain removal or routine change should be agreed with the referring clinical team |
| Special considerations | ● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients, especially in children and pregnant women.<br>● Careful review of any cross-sectional imaging is recommended to avoid causing damage to colon<br>● Persistent bleeding and instability may require angiography with possible embolization.<br>● Locking or non-locking drains may be used (non-locking drains should be sutured in place to avoid inadvertent removal) |

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| Modifications | • Direct puncture technique may be considered in patients with straightforward access to collecting system if guidewire/needle combination are not available.<br>• PCN can often be performed entirely under ultrasound guidance to reduce screening time. Tube placement can be confirmed with the instillation of agitated saline |
| References | • https://www.jvir.org/article/S1051-0443%2815%2901140-9/pdf?code=jvir-site<br>• https://www.acr.org/-/media/ACR/Files/Practice-Parameters/percutaneous-nephros.pdf?la=en |

| **3.2 Percutaneous cholecystostomy** | |
|---|---|
| Indications | • Alleviate severe acute cholecystitis, empyema, pericholecystic abscess, cholangitis, biliary obstruction, cholelithiasis dissolution, or gallbladder perforation in patients deemed too high risk for surgery (e.g. age, comorbidities, malignancy, sepsis, pregnant) |
| Contraindications | • Relative – Coagulopathy (target INR <1.5; Plt >50,000), Iodine allergy (e.g. fluoroscopic-guided PC), ascites, severe cholelithiasis, interposed bowel |
| Procedure specific risks | • Damage to adjacent structures depending on route used: pneumothorax; bowel perforation; biliary-cutaneous fistula; bile leak > biliary peritonitis; bleeding; infection |
| Alternative Interventions | • Endoscopic ultrasound-guided gallbladder drainage with stents<br>• Cholecystectomy<br>• Conservative management |
| Technique | • Transhepatic (common): catheter stability, reduces bile leakage, quicker maturation for the catheter track, preferred in patients with ascites or interposed bowel \| higher risk of bleeding, pneumothorax, and fistula formation<br>• Anterior/Anterolateral transperitoneal: preferred in patients with diffuse liver disease or coagulopathy \| approach precluded by friable gallbladder<br>• Seldinger: access to GB with dilation and insertion of cholecystostomy tube<br>• Trocar (direct): Insertion of cholecystostomy tube in single pass |

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| Equipment | ● Imaging: Ultrasound (curvilinear probe), fluoroscopy, or CT<br>● Basic pack<br>● Medications: IV analgesics, local anesthesia<br>● Sample pot / specimen form for microbiology<br>● Access needle (22g-18g)<br>● Guidewire<br>● Dilatators (for Selginger technique)<br>● Cholecystotomy tube (5F-8F size; pigtail, cope loop, accordion)<br>● Closure: Suture/drain-fix dressing, sterile skin dressing<br>● *Optional:* cholangiogram |
| Aftercare | ● Patients rest in bed for 2 hours post procedure to reduce the risk of bleeding. Respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected<br>● Stitches should be removed at an agreed interval<br>● Twice daily tube drain rinse with 10 mL of normal saline<br>● Longer-term plan for drain removal or routine change should be agreed with the referring clinical team (usually 3-6 weeks) |
| Special considerations | ● Tube placement can be confirmed with the instillation of contrast.<br>● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients, especially in children and pregnant women.<br>● Locking or non-locking drains may be used. Non-locking drains, where used, should be sutured in place to avoid inadvertent removal |
| References | ● Lindemann, Steven R., et al. "Percutaneous Cholecystostomy-A Review." Seminars in interventional radiology. Vol. 5. No. 03. Copyright© 1988 by Thieme Medical Publishers, Inc., 1988.<br>● Venara, A., et al. "Technique and indications of percutaneous cholecystostomy in the management of cholecystitis in 2014." Journal of visceral surgery 151.6 (2014): 435-439.<br>● Gulaya, Karan, Shamit S. Desai, and Kent Sato. "Biliary Interventions: Percutaneous Cholecystostomy: Evidence-Based Current Clinical Practice." Seminars in interventional radiology. Vol. 33. No. 4. Thieme Medical Publishers, 2016. |

## 3.3 Percutaneous gastrostomy

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|---|---|
| Indications | • Enteral access for patients requiring long-term nutritional support for a variety of conditions |
| Contraindications | • Absolute - No safe access to stomach<br>• Relative – Coagulopathy (target INR <1.5; Plt >50,000) |
| Procedure specific risks | • Damage to adjacent structures – small bowel, colon; bleeding; infection - peritonitis |
| Alternative Interventions | • Surgical or endoscopic placement<br>• Parenteral nutrition |
| Technique | • Fluoroscopy guided, CT guided<br>• Push: Common to place gastropexy (1-4) followed by 14F catheter or 16-20F MIC gastrostomy tube<br>• Pull: Single access and 20F mushroom type gastrostomy with long taper advanced over the wire after access out of the oral cavity through the GE junction |
| Equipment | • Imaging: Ultrasound, fluoroscopy, and/or CT<br>• Basic pack<br>• Medications: IV analgesics, local anesthesia, glucagon<br>• Gastropexy kit<br>• Access needle (19g or sheathed needle)<br>• Guidewire (260cm + for pull type)<br>• Dilatators (for push type)<br>• Gastrostomy tube (14F-20F size; Ponsky, MIC, pigtail)<br>• Securing: Suture or disk/balloon retention |
| Aftercare | • Gastrostomy tube to remain to drainage for 6-24 hours prior to being cleared for feeds.<br>• Respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected.<br>• Gastropexy should be removed at an agreed interval (7-10 days) |

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| Special considerations | • Exchange can be made once track mature (6-8 weeks) for low profile or larger caliber tube.<br>• Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients.<br>• Balloon assisted gastrostomy can be performed instead of serial dilatation of the track. |
| References | • https://www.ajronline.org/doi/full/10.2214/AJR.11.7804<br>• Kandarpa, Krishna, et al. Handbook of Interventional Radiologic Procedures, Wolters Kluwer Health, 2016. ProQuest Ebook Central, https://ebookcentral-proquest-com.eresources.mssm.edu/lib/icahn-mssm/detail.action?docID=4931416. |

| ***3.4 Percutaneous Cholangiogram (PTC) and Biliary Drain Insertion (PTBD)*** | |
|---|---|
| Indications | • Biliary obstruction secondary to malignancy, stone, benign stricture<br>• Bile leak<br>• Failed endoscopic approach to biliary drainage<br>• Surgical anatomy precludes an endoscopic approach |
| Contraindications | • Absolute – no safe access, multiple<br>• Relative - Coagulopathy (target INR <1.5; Plt >50,000), contrast allergy, ascites (drainage may be required prior to PTC/PTBD) |
| Procedure specific risks | • An obstructed biliary system that is accessed percutaneously puts the patient at risk for bacteremia and sepsis<br>• Bleeding<br>• Vascular injury: pseudoaneurysm and biliary to portal vein, hepatic vein or hepatic artery fistula<br>• Injury to adjacent structures: bowel injury, pneumothorax |

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| Alternative Interventions | • Endoscopic placement |
| Technique | • Review available labs: ideally platelets above 50 K and INR above 1.5.<br>• US guided, Fluoroscopy guided, US/fluoroscopy guided<br>• Pre-procedure antibiotics<br>• Needle access under image-guidance<br>• Wire access to biliary system via 22 – 18 g needle, standard upsizing technique using transition dilator to 035 system if necessary and placement typically of 8 or 10 Fr drain.<br>• 21 or 22 g needle preferred if available, particularly for fluoroscopically guided approach<br>• Right Lobe vs Left Lobe Access: pros and cons<br>• Obstructed vs decompressed systems: ultrasound approach using curvilinear probe for obstructed systems, fluoroscopic approach for decompressed systems secondary to bile leak.<br>• PTC: cholangiogram may be performed with gently injection of contrast to delineate anatomy, level of obstruction, leak etc. |
| Equipment | • Imaging: Ultrasound and fluoroscopy<br>• Basic pack<br>• Medications: IV analgesics, local anesthesia<br>• Guidewires: 018 and 035 wires<br>• Appropriate Dilators<br>• Appropriate Biliary Drain: 8 – 10 Fr<br>• Closure: Suture/drain-fix dressing, sterile skin dressing |
| Aftercare | • To gravity drain<br>• Daily flushing with sterile saline<br>• Consideration of definitive management of underlying condition<br>• Cholangiogram can be performed at later date, after system decompressed and risk of sepsis diminished |

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| Special considerations | • Tube placement can be confirmed with the instillation of contrast.<br>• Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients, especially in children and pregnant women.<br>• Locking drains may preferred. Non-locking drains, where used, should be sutured in place to avoid inadvertent removal. Their use and removal procedure should be clearly documented to aid clinical team at the time of removal. |
| References | • Altman A, Zangan SM. Benign Biliary strictures. Semin Intervent Radiol 2016;33:297-306<br>• Kapoor BS, Mauri G, Lorenz JM. Management of biliary strictures: State-of-the-art review. Radiology 2018;289:590-603 |

| **4.1 Pelvic trauma embolization** | |
|---|---|
| Indications | • Active bleeding after pelvic trauma<br>• Hemodynamic instability and pelvic fracture |
| Contraindications | • Relative – Uncorrectable coagulopathy |
| Procedure specific risks | • Rebleeding, persistent bleeding<br>• Non-target embolization<br>• Complications relating to access eg hematoma/thrombus/dissection |
| Alternative Interventions | • Conservative management<br>• Surgery |

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|---|---|
| Equipment | ● Equipment for arterial access including local anesthesia<br>● Procedure pack<br>● 5-6 Fr introducer sheath, 4-5Fr diagnostic and selective catheter; optional microcatheters<br>● Guidewire (optional microwires)<br>● Embolic agent eg. coils, gelfoam<br>● Closure: Femoral closure device, sterile skin dressing |
| Aftercare | ● Patients rest in bed post operatively with monitoring respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected |
| Special considerations | ● Empiric embolization of the internal iliac mostly used when there is diffuse bleeding, when multiple focal bleeding vessels exist, when patient is unstable, where site of bleeding not identified; however increased risk of gluteal ischemia with bilateral embolization<br>● Selective embolization preferred and performed for focal arterial source of bleeding |
| References | ● Martin et al. Evaluation and Treatment of Blunt Pelvic Trauma. Tech Vasc Interventional Rad. 2017;20:237-242.<br>● Fangio et al. Early Embolization and Vasopressor Administration for Management of Life-threatening hemorrhage from pelvic fracture. J Trauma. 2005;58:978-984.<br>● Ben-Menachem et al. Hemorrhage Associated with Pelvic Fractures: Causes, Diagnosis and Emergent Management. AJR. November 1991;157:1005-1012.<br>● Papakostidis et al. The role of arterial embolization in controlling pelvic fracture hemorrhage: A systematic review of the literature. European Journal of Radiology. 2012;81:897-904. |

| **4.2 Hepatic artery trauma embolization** | |
|---|---|
| Indications | ● Active bleeding after penetrating or blunt trauma to the liver |

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| Contraindications | ● Relative – Uncorrectable coagulopathy |
| Procedure specific risks | ● Rebleeding, persistent bleeding<br>● Non-target embolization<br>● Liver failure<br>● Complications relating to access eg hematoma/thrombus/dissection |
| Alternative Interventions | ● Conservative management<br>● Surgery |
| Equipment | ● Equipment for arterial access including local anesthesia<br>● Procedure pack<br>● 5-6 Fr introducer sheath, 4-5 Fr diagnostic and selective catheter; optional microcatheters<br>● Guidewire (optional microwires)<br>● Embolic agent eg. coils, particles, gelfoam<br>● Closure: Femoral closure device, sterile skin dressing |
| Aftercare | ● Patients rest in bed post operatively with monitoring respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected<br>● Monitor liver function tests |
| Special considerations | ● Important to identify hepatic arterial variants<br>● If diffuse bleeding, when multiple focal bleeding vessels exist, when patient is unstable can consider non-selective lobar embolization with gelfoam<br>● Selective embolization preferred and performed for focal arterial source of bleeding<br>● If active extravasation or pseudoaneurysm of proximal branch can consider stent graft if feasible |
| References | ● Martin et al. Evaluation and Treatment of Blunt Pelvic Trauma. Tech Vasc Interventional Rad. 2017;20:237-242.<br>● O'Dell et al. Emergent Endovascular Treatment of Penetrating Trauma: Solid Organ and Extremity. Tech Vasc Interventional Rad. 2017;20:243-247. |

| **4.3 Renal artery trauma embolization** | |
|---|---|
| Indications | ● Active extravasation, pseudoaneurysm, AVF or enlarging perinephric hematoma after penetrating or blunt trauma to the kidney<br>● Refractory hematuria |
| Contraindications | ● Relative – Uncorrectable coagulopathy, hemodynamic instability |
| Procedure specific risks | ● Rebleeding, persistent bleeding<br>● Non-target embolization<br>● Renal failure<br>● Complications relating to access eg hematoma/thrombus/dissection |
| Alternative Interventions | ● Conservative management<br>● Surgery |
| Equipment | ● Equipment for arterial access including local anesthesia<br>● Procedure pack<br>● 5-6 Fr introducer sheath, 4-5 Fr diagnostic and selective catheter; optional microcatheters<br>● Guidewire (optional microwires)<br>● Embolic agent eg. coils, particles, gelfoam<br>● Closure: Femoral closure device, sterile skin dressing |
| Aftercare | ● Patients rest in bed post operatively with monitoring respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected<br>● Monitor kidney function tests |
| Special considerations | ● Important to identify renal arteries including accessory and capsular branches<br>● Selective embolization needed to spare as much renal parenchyma as possible<br>● If active extravasation or pseudoaneurysm of proximal branch can consider stent graft if feasible |

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| References | ● Martin et al. Evaluation and Treatment of Blunt Pelvic Trauma. Tech Vasc Interventional Rad. 2017;20:237-242.<br>● O'Dell et al. Emergent Endovascular Treatment of Penetrating Trauma: Solid Organ and Extremity. Tech Vasc Interventional Rad. 2017;20:243-247. |

| **4.4 Splenic artery trauma embolization** | |
|---|---|
| Indications | ● Active bleeding after splenic trauma<br>● Prevent delayed splenic rupture |
| Contraindications | ● Absolute - Hemodynamic instability requiring operative intervention |
| Procedure specific risks | ● Rebleeding, persistent bleeding<br>● Splenic infarction / abscess<br>● Non-target embolization<br>● Bleeding<br>● Complications relating to access eg hematoma/thrombus/dissection |
| Alternative Interventions | ● Conservative management<br>● Surgery |
| Equipment | ● Equipment for arterial access including local anesthesia<br>● Procedure pack<br>● 5-6 Fr introducer sheath, 4-5Fr diagnostic catheter; optional microcatheters<br>● Guidewire (optional microwires)<br>● Embolic agent eg. coils; plugs; gelfoam<br>● Closure: Suture/drain-fix dressing, sterile skin dressing |
| Aftercare | ● Patients rest in bed post operatively with monitoring respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected |

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|---|---|
| Special considerations | ● Proximal embolization mostly used when there is diffuse splenic bleeding, when multiple focal bleeding vessels exist, when patient is unstable, where site of bleeding not identified<br>● Distal embolization sometimes performed for focal arterial source of bleeding<br>● Pay attention to location of collateral supply to spleen to preserve splenic arterial supply and function (eg. left gastric artery; dorsal pancreatic artery |
| References | ● Van der Vlies, Cornelis H., et al. "Literature review of the role of ultrasound, computed tomography, and transcatheter arterial embolization for the treatment of traumatic splenic injuries." *Cardiovascular and interventional radiology* 33.6 (2010): 1079-1087. |

| **4.5 Bronchial Artery Embolization** | |
|---|---|
| Indications | ● Massive hemoptysis: >300 mL/24 hours<br>● Recurrent bouts of moderate hemorrhage: >100 mL three times per week<br>● Chronic/slowly increasing hemoptysis<br>● Poor surgical candidates |
| Relative Contraindications | ● Presence of spinal artery arising from bronchial artery<br>● Respiratory compromise (inability to lie flat) |
| Procedure specific risks | ● Spinal cord ischemia/transverse myelitis<br>● Chest pain<br>● Non-target embolization of esophagus<br>● Bleeding, infection, and damage to adjacent structures such as nerves, arteries or veins<br>● Inherent risks of sedation/anesthesia |
| Equipment | ● Vascular access equipment<br>● Contrast, sheath, catheters/microcatheters for access<br>● Embolization particles >500-700μm, or other suitable embolic agent |
| Aftercare | ● Bed rest and observation in immediate post-procedural period, with monitoring of respiratory rate, heart rate and blood pressure<br>● Assessment for recurrence of hemorrhage |

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| Special considerations | • Chest x-ray, CT scan and bronchoscopy can be utilized pre-procedurally to help determine likely location of hemorrhage and arterial anatomy<br>• Angiographic findings:<br>  ○ Active extravasation (only in ~10% of cases)<br>  ○ Vascular hypertrophy/tortuosity<br>  ○ Neovascularity/hypervascularity<br>  ○ Aneurysm formation<br>• Thoracic arterial contributions to the anterior spinal artery must be assessed to prevent spinal cord infarction |
| References | • https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3140255/pdf/sir28048.pdf<br>• https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3036206/pdf/sir21043.pdf |

| **4.6 Inferior epigastric artery embolization** | |
|---|---|
| Indications | • Active bleeding |
| Contraindications | • Relative – Coagulopathy (target INR <1.5; Plt >50,000) |
| Procedure specific risks | • Rebleeding, persistent bleeding<br>• Non-target embolization<br>• Complications relating to access eg hematoma/thrombus/dissection |
| Alternative Interventions | • Conservative management<br>• Surgery |
| Equipment | • Equipment for arterial access including local anesthesia<br>• Procedure pack<br>• 5-6 Fr introducer sheath, 4-5Fr diagnostic catheter; optional microcatheters<br>• Guidewire (optional microwires)<br>• Embolic agent eg. coils; plugs; gelfoam; glue<br>• Closure: Suture/drain-fix dressing, sterile skin dressing |

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| Aftercare | • Patients rest in bed post operatively with monitoring respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected |
| Special considerations | • Can consider ipsilateral approach or contralateral approach depending on origin of the inferior epigastric artery.<br>• Avoid reflux of embolic into the common femoral artery |
| References | • Sobkin et al. Massive abdominal wall hemorrhage from injury to the inferior epigastric artery: a retrospective review. J Vasc Interv Radiol. 2008 Mar;19(3):327-32. |

| **4.7 Pre-operative bland embolization** | |
|---|---|
| Indications | • Hypervascular lesion prior to surgery to limit blood loss |
| Contraindications | • Relative – Coagulopathy (target INR <1.5; Plt >50,000) |
| Procedure specific risks | • Non-target embolization<br>• Infection<br>• Complications relating to access eg hematoma/thrombus/dissection |
| Alternative Interventions | • Surgery without embolization |
| Equipment | • Equipment for arterial access including local anesthesia<br>• Procedure pack<br>• 5-6 Fr introducer sheath, 4-5Fr diagnostic catheter; optional microcatheters<br>• Guidewire (optional microwires)<br>• Embolic agent eg. gelfoam; particles; glue<br>• Closure: Suture/drain-fix dressing, sterile skin dressing |
| Aftercare | • Patients rest in bed post operatively with monitoring respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected. |

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| Special considerations | • Isolate as many branches that supply lesion as possible with goal to obtain stasis.<br>• Recommend particle sizes between 300-900 microns |
| References | • Riling et al. Preoperative Embolization. Semin Intervent Radiol. 2004 Mar; 21(1): 3–9. |

## *Complex procedures*

| **5.1 Percutaneous tumour ablation** | |
|---|---|
| Indications | • Tumour determined appropriate for percutaneous ablation by tumor board / multi-disciplinary discussion<br>• Vary with tumor type and location (lung, liver, renal)<br>• Methods of solid tumor ablation can include chemical (ethanol injection) or thermal (cryoablation, microwave ablation, RFA, HIFU, IRE) |
| Contraindications | • Absolute – No safe access to lesion<br>• Relative – Coagulopathy (target INR <1.5; Plt >50,000); other treatment deemed more appropriate |
| Procedure specific risks | • Depends on method of ablation<br>• Bleeding<br>• Incomplete treatment<br>• Chemical or thermal injury to normal tissue or adjacent structures |
| Alternative Interventions | • Depends on tumor location and type, may include surgery, chemotherapy, radiation |
| Equipment | • Basic pack<br>• Equipment for safe access into lesion (imaging, coaxial needles)<br>• Ablation equipment including probes |
| Aftercare | • Depends on tumor location and treatment<br>• Analgesia as required<br>• Follow-up imaging to determine tumor response |
| Special considerations | • Ethanol has been shown effective in treating small HCCs (cure rates similar to surgery in selective patients)<br>• MWA can generate high temperatures in less time with less susceptibility to heat sink<br>• RFA treatment may be limited by tissue charring (acts as insulation) and heat sink effect of large adjacent blood vessels<br>• Cryoablation is used in areas where there are vulnerable surrounding structures, the treatment of large tumours may require placement of multiple needles and the ice-ball can be easily visualised on imaging |

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| References | ● Lung cancer ablation: technologies and techniques. Alexander ES, Dupuy DE. Semin Intervent Radiol. 2013 Jun; 30(2):141-50.<br>● CIRSE Guidelines on Percutaneous Ablation of Small Renal Cell CarcinomaKrokidis, M.E., Orsi, F., Katsanos, K. et al. Cardiovasc Intervent Radiol (2017) 40: 177. |

| **5.2 Vertebral Augmentation** | |
|---|---|
| Indications | ● Recent traumatic vertebral fracture<br>● Recent osteoporotic vertebral fracture refractory to medical therapy<br>● Symptomatic hemangioma<br>● Painful malignant involvement of vertebrae |
| Contraindications | ● Absolute – Cord compression, infection<br>● Relative – Coagulopathy (target INR <1.5; Plt >50,000) |
| Procedure specific risks | ● Cord compression<br>● Infection<br>● Non-target cement administration |
| Alternative Interventions | ● Medical management (NSAIDs, PT)<br>● Surgical |
| Equipment | ● Basic pack<br>● Vertebral augmentation kit (needles, cannula, pump, hammer)<br>● Cement (PMMA) |
| Aftercare | ● Pain medication as needed<br>● Continue ambulation but avoid strenuous activity for several weeks |
| Special considerations | ● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients.<br>● Can be combined with thermal ablation (RF, MWA) for malignant processes<br>● Posterior involvement should be avoided if significant risk of cord compression<br>● Bi-plane can be helpful for localization and needle placement |

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| References | ● Filippiadis et al. Percutaneous Vertebroplasty and Kyphoplasty: Current Status, New Developments and Old Controversies. Cardiovasc Intervent Radiol (2017) 40:1815–1823. |

| **5.3 Pleurodesis** | |
|---|---|
| Indications | ● Recurrent pleural effusion, intercostal pleural draining <100ml/day<br>● Recurrent pneumothorax |
| Contraindications | ● Absolute – Allergy to sclerotic agent<br>● Relative – Coagulopathy (target INR <1.5; Plt >50,000), surgical procedure more appropriate |
| Procedure specific risks | ● Pneumothorax |
| Alternative Interventions | ● Conservative management<br>● Surgical intercostal drain insertion then pleurodesis |
| Equipment | ● Basic pack<br>● Seldinger intercostal drainage kit<br>● Underwater seal drain<br>● Sclerosing agent for injection through drain<br>● General anesthesia usually |
| Aftercare | ● Pain medication as needed<br>● Remove drain after 24h<br>● Chest radiograph to exclude significant pneumothorax |
| Special considerations | ● Different usage instructions for different available sclerosing agents |

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| References | • Indwelling Pleural Catheter versus Pleurodesis for Malignant Pleural Effusions. A Systematic Review and Meta-Analysis. Iyer NP, Reddy CB, Wahidi MM, Lewis SZ, Diekemper RL, Feller-Kopman D, Gould MK, Balekian AA. Ann Am Thorac Soc. 2019 Jan;16(1):124-131. |

| **5.5 Fallopian tube recanalization** | |
|---|---|
| Indications | • Infertility due to proximal fallopian tube occlusion (20% to 40% of female infertility is due to tubal disease)<br>• Re-occlusion after surgical reversal of tubal ligation |
| Contraindications | • Absolute – Active infection, intrauterine adhesions<br>• Relative – Coagulopathy (target INR <1.5; Plt >50,000) |
| Procedure specific risks | • Tubal perforation<br>• Infection<br>• Tubal pregnancy |
| Alternative Interventions | • Surgery |
| Equipment | • Basic pack<br>• HSG kit with speculum<br>• Angled catheter and hydrophilic wire<br>• Microcatheter and wire |
| Aftercare | • Advise patient that spotting and cramping can be seen for a few days after procedure<br>• Patient to use pad not tampon for next cycle and avoid intercourse for 24 hours |
| Special considerations | • Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients.<br>• High success rate for proximal tubal occlusion |

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| References | ● Kandarpa, Krishna, et al. Handbook of Interventional Radiologic Procedures, Wolters Kluwer Health, 2016. ProQuest Ebook Central, https://ebookcentral-proquest-com.eresources.mssm.edu/lib/icahn-mssm/detail.action?docID=4931416. |

| **6.1.1 Uterine artery embolization** | |
|---|---|
| Indications | ● Symptomatic uterine fibroids (leiomyomata) where patients have failed conservation management<br>● Uncontrolled post-partum vaginal bleeding secondary to uterine atony, tumors or iatrogenic injury<br>● Fibroid embolization prior to resection |
| Contraindications | ● Absolute – pregnancy, active pelvic infection, suspected malignancy, vaginal bleeding post menopause<br>● Relative – Coagulopathy (target INR <1.5; Plt >50,000) |
| Procedure specific risks | ● Arterial injury<br>● Non-target embolization<br>● Premature menopause |
| Alternative Interventions | ● Medical management<br>● Surgical (myomectomy, hysterectomy) |
| Equipment | ● Angio pack<br>● Vascular access equipment<br>● Embolic material (eg 500-700micron particles for fibroid embolisation; gelfoam slurry for PPH) |
| Aftercare | ● Pain medication as needed (some patients require opioid analgesia +/- PCA)<br>● Warn patients treated for fibroids of potential passing of fibroid material / discharge |
| Special considerations | ● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients. |

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| References | ● Updates on Uterine Artery Embolization. Kohi MP, Spies JB. Semin Intervent Radiol. 2018 Mar;35(1):48-55.<br>● Endovascular Therapies for Primary Postpartum Hemorrhage: Techniques and Outcomes. Matthew G. Gipson, Mitchell T. Smith. Semin Intervent Radiol. 2013 Dec; 30(4): 333–339. |

| **6.1.2 Gonadal vein embolization** | |
|---|---|
| Indications | ● Symptomatic varicocoele (male patient), male infertility<br>● Pelvic congestion syndrome (female patient) |
| Contraindications | ● Absolute – symptoms attributed to another cause, no safe access to pelvic veins<br>● Relative – Coagulopathy (target INR <2.0; Plt >50,000) |
| Procedure specific risks | ● Non-target embolization<br>● Access vessel injury, thrombophlebitis<br>● Radiation exposure to ovaries (female) |
| Alternative Interventions | ● Conservative and medical management<br>● Surgery (laparoscopic ligation of testicular vein) |
| Equipment | ● Angio pack<br>● Vascular access equipment<br>● Embolic material (varies with procedure) |
| Aftercare | ● Clinic follow-up |
| Special considerations | ● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients. |

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| References | ● Gonadal Vein Embolization: Treatment of Varicocele and Pelvic Congestion Syndrome. Mark A. Bittles, Eric K. Hoffer. Semin Intervent Radiol. 2008<br>● Female Pelvic Vein Embolization: Indications, Techniques, and Outcomes. Anthony James Lopez. Cardiovasc Intervent Radiol. 2015; 38(4): 806–820. |

| **6.1.3 Prostate artery embolization** | |
|---|---|
| Indications | ● Benign prostatic hyperplasia causing symptoms of urinary outflow obstruction |
| Contraindications | ● Absolute – symptoms attributed to another cause, no safe access to prostatic arteries<br>● Relative – Coagulopathy (target INR <1.5; Plt >50,000) |
| Procedure specific risks | ● Non-target embolization<br>● Access vessel injury |
| Alternative Interventions | ● Conservative and medical management<br>● Surgery (including transurethral prostatic resection, prostatectomy) |
| Equipment | ● Angio pack<br>● Vascular access equipment<br>● Microcather and microguidewires<br>● Particulate embolic agent (check compatibility with microcatheter) |
| Aftercare | ● Clinic follow-up |
| Special considerations | ● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients.<br>● Care should be taken to identify important collaterals prior to embolization and avoid reflux during injection of embolic |

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| References | ● UK NICE guidelines for PAE: http://www.bjuinternational.com/learning-2/urology-guidelines/nice-guidance-prostate-artery-embolisation-lower-urinary-tract-symptoms-caused-benign-prostatic-hyperplasia/ |

| **6.1.4 Liver tumor embolization (TAE) and chemoembolization (TACE) and radioembolization (TARE)** | |
|---|---|
| Indications | ● Oncology patients with a liver-predominant tumor burden eg. HCC; CRLC metastases; NET<br>● AND transarterial embolization determined as most appropriate treatment by multidisciplinary tumor board (specific indications will vary by tumor, patient factors, underlying liver disease, local practice and staging systems) |
| Contraindications | ● Absolute – decompensated liver disease<br>● Relative – unable to safely undergo arteriography, significant liver impairment, biliary-enteric anastomosis, uncorrectable coagulopathy |
| Procedure specific risks | ● Non-target embolization<br>● Post embolization syndrome<br>● Abscess formation<br>● Liver failure<br>● Access vessel injury precluding treatment |
| Alternative Interventions | ● Management options available depend on status of patient and tumor type and stage<br>● Input from local multidisciplinary tumour review board |
| Equipment | ● Angio pack<br>● Vascular access equipment<br>● Microcrater and microwires<br>● Appropriate liquid or particulate embolic agent (check compatibility with microcatheter) may include chemotherapy emulsion; drug eluting beads; Y90 microspheres |
| Aftercare | ● Clinic follow-up<br>● Imaging to determine treatment response at regular intervals |

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| Special considerations | • Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients.<br>• Pre-TARE work-up is necessary to determine presence of lung shunt (radio-labelled MAA) and the arterial supply, pre-TARE consolidating embolization may be required<br>• Stringent safety precaution should be followed when handling chemotherapeutic agents during TACE including eye and skin protection and safe disposal<br>• Radiation dose to the operator should be considered during TARE and special handling precautions followed |
| References | • SIR guidelines for liver TACE 2017: Quality Improvement Guidelines for Transarterial Chemoembolization and Embolization of Hepatic Malignancy accessed at https://www.jvir.org/article/S1051-0443(17)30471-2/pdf<br>• Standards of practice in transarterial radioembolization. Mahnken AH, Spreafico C, Maleux G, Helmberger T, Jakobs TF. Cardiovasc Intervent Radiol. 2013 Jun<br>• Current status of transarterial radioembolization. Andreas H Mahnken. World J Radiol. 2016 May 28; 8(5): 449–459. |

| **6.1.5 Vascular malformation treatment** | |
|---|---|
| Indications | • Symptomatic lesion<br>• Treatment depends on lesion, lesions include hemangiomata, arterio-venous malformations (AVMs); venous malformations (VMs); arteriovenous fistula (AVF); lymphatic malformation<br>• Treatment should be performed in conjunction with multidisciplinary practice including surgeons and psychological support |
| Contraindications | • Relative – Coagulopathy (target INR <1.5; Plt >50,000) |
| Procedure specific risks | • Non-target embolization<br>• Ethanol ablation is usually painful and can result in systemic ethanol toxicity<br>• Necrosis of overlying skin/mucous membranes (MM) |

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| Alternative Interventions | ● Conservative<br>● Surgery usually not recommended as first line management |
| Equipment | ● Angio pack<br>● Vascular access equipment<br>● Appropriate sclerosant or embolic material |
| Aftercare | ● Pain medication as needed<br>● Close monitoring of skin/MM integrity |
| Special considerations | ● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients.<br>● Repeated interventions may be required |
| References | ● Vascular anomalies: classification, imaging characteristics and implications for interventional radiology treatment approaches. P R Mulligan, H J S Prajapati, L G Martin, T H Patel. Br J Radiol. March 2014; 87(1035)<br>● Vascular Malformations: A Review. Joshua A. Cox, Erica Bartlett, Edward I. Lee. Semin Plast Surg. 2014 May; 28(2): 58–63. |

| **6.1.6 Portal vein embolization** | |
|---|---|
| Indications | ● To increase future liver remnant volume (FLR) prior to hepatic resection for tumor |
| Contraindications | ● Absolute – severe portal hypertension; portal vein occlusion/infiltration by tumor; uncontrolled portal-hepatic vein shunt<br>● Relative – Coagulopathy (target INR <1.5; Plt >50,000) |
| Procedure specific risks | ● Non-target embolization<br>● Damage to FLR or portal vein rendering patient inoperable<br>● Liver failure |

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| Alternative Interventions | ● Surgical PV ligation/ALPSS<br>● Y90 radioembolization |
| Equipment | ● Angio pack<br>● Ultrasound for transhepatic PV access (usual route)<br>● Sheath/catheter/microcatheter for embolic delivery<br>● Appropriate sclerosant or embolic material |
| Aftercare | ● Pain medication as needed<br>● Close monitoring of LFTs immediately following the procedure<br>● Imaging follow-up at appropriate interval to determine response |
| Special considerations | ● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients.<br>● Care should be taken with the PV access (avoiding tumor, usually avoiding FLR if possible) |
| References | ● Portal Vein Embolization Before Liver Resection: A Systematic Review. K. P. van Lienden, J. W. van den Esschert, W. de Graaf, S. Bipat, J. S. Lameris, T. M. van Gulik, O. M. van Delden. Cardiovasc Intervent Radiol. 2013 Feb; 36(1): 25–34.<br>● Portal Vein Embolization as an Oncosurgical Strategy Prior to Major Hepatic Resection: Anatomic, Surgical, and Technical Considerations. Sonia T. Orcutt, Katsuhiro Kobayashi, Mark Sultenfuss, Brian S. Hailey, Anthony Sparks, Bighnesh Satpathy, Daniel A. Anaya. Front Surg. 2016; 3: 14. |

| **6.2 Endovascular Aortic Repair for aneurysmal disease (EVAR)** | |
|---|---|
| Indications | ● AAA >50 mm diameter (or agreed size criteria)<br>● Rapidly expanding AAA<br>● Contained rupture / stable patient<br>● Inflammatory AAA<br>● High-risk patient for open repair |
| Contraindications | ● Absolute – no safe endovascular option; unable to introduce graft from access vessels (femoral); surgery deemed more appropriate |

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| | ● Relative – aneurysm anatomy is non-compliant with graft manufacturers indications for use (IFU); mycotic aneurysm; need to preserve IMA, coagulopathy (target INR <1.5; Plt >50,000) |
| Procedure specific risks | ● Damage to access vessels<br>● Aneurysm rupture<br>● Coverage of renal arteries with stent graft<br>● Complication requiring on-table conversion to open surgery<br>● Endoleaks – continued perfusion of the aneurysm sac requiring further treatment, long-term follow-up and which can lead to aneurysm rupture |
| Alternative Interventions | ● Surgical repair<br>● Conservative management |
| Equipment | ● Angio pack<br>● Equipment for vascular access including large bore closure<br>● Stent graft on delivery system<br>● Stiff exchange length wires (eg. Lundquist)<br>● Pigtail flush catheter<br>● Catheter/wire for cannulation of the contralateral limb |
| Aftercare | ● Monitoring for endoleak, graft migration, component dislocation and stent fracture |
| Special considerations | ● Proper planning and graft sizing is imperative to the procedure success, grafts should be planned in accordance with the manufacturers instructions<br>● “Complex” aneurysm anatomy may necessitate additional endovascular procedures eg branched/fenestrated repair; snorkel/chimney techniques<br>● Adjunctive procedures may be required to access vessels to allow passage of graft<br>● Can be performed percutaneously if there is availabiity for large-bore (18-24F) percutaneous closure<br>● Heparin should be administered during the procedure (+/- ACT monitoring according to local vascular surgery guidelines) |
| References | ● Standards of practice guidelines: https://www.jvir.org/article/S1051-0443(10)00761-X/abstract |

| **6.3 Thoracic aortic endovascular repair (TEVR)** | |
|---|---|
| Indications | ● Blunt traumatic aortic injury (BTAI) with pseudoaneurysm formation or free rupture (usually do not survive to intervention) |
| Contraindications | ● Absolute – non-survivable injuries<br>● Relative – treatment can be delayed while other injuries are managed |
| Procedure specific risks | ● Damage to access vessels<br>● Coverage of great vessel origins with stent graft, may necessitate surgical bypass |
| Alternative Interventions | ● Medical management<br>● Surgery |
| Equipment | ● Angio pack<br>● Equipment for vascular access including large bore closure<br>● Stent graft on delivery system<br>● Stiff exchange length wires (eg. Lundquist)<br>● Pigtail flush catheter |
| Aftercare | ● Monitoring for late complications of thoracic stent insertion (stent migration/fracture) |
| Special considerations | ● Proper planning and graft sizing is key. Stent grafts should be sized in accordance with the manufacturers instructions<br>● Adjunctive procedures may be required to access vessels to allow passage of graft<br>● Can be performed percutaneously if there is availability for large-bore (18-24F) percutaneous closure<br>● Usually heparin is not administered in the setting of traumatic aortic injury |
| References | ● Evaluation and management of blunt traumatic aortic injury: a practice management guideline from the Eastern Association for the Surgery of Trauma. Fox N et al. J Trauma Acute Care Surg. 2015 Jan;78(1):136-46. |

| **6.4 Arterial thrombolysis / thrombectomy** | |
|---|---|
| Indications | ● Acute arterial occlusion of the limb secondary to embolus or thrombus formation |
| Contraindications | ● Absolute – non-viable limb<br>● Relative – uncorrectable coagulopathy |
| Procedure specific risks | ● Damage to access vessels<br>● Clot fragmentation and distal embolisation<br>● Major haemorrhage secondary to pharmacological thromboysis |
| Alternative Interventions | ● Surgical thrombectomy |
| Equipment | ● Angio pack<br>● Equipment for vascular access<br>● Catheter and sheath<br>● Thrombectomy or thrombolysis equipment (eg infusion catheter and appropriate pharmaceutical; aspiration catheter; mechanical thrombectomy device) |
| Aftercare | ● If leaving infusion running then patient should return for follow-up angiogram +/- further procedure / thrombectomy |
| Special considerations | ● Consideration should be given to systemic heparinization in order to prevent thrombus propagation<br>● If pharmacological thrombolysis is ongoing, patient should be closely monitored for hemorrhagic complications and condition of affected limb |
| References | ● CIRSE standards of practice for thrombolysis in acute lower limb ischaemia: https://eu-csite-storage-prod.s3.amazonaws.com/www-cirse-org/files/files/SOP/2011/SOP_CIRSE_2011_Percutaneous%20Catheter-Directed%20Intra- |

| | |
|---|---|
| | Arterial%20Thrombolysis%20and%20Mechanical%20Thrombectomy%20for%20Acute%20Lower-Limb%20Ischemia.pdf |

| **6.5 Peripheral arterial intervention** | |
|---|---|
| Indications | ● Chronic limb ischemia causing significant symptoms unresponsive to conservative management (lifestyle modification, supervised exercise programs) and in patients where endovascular intervention is most appropriate |
| Contraindications | ● Absolute – non-viable limb<br>● Relative – single tibial vessel runoff, disease more appropriate for surgical management, uncorrectable coagulopathy |
| Procedure specific risks | ● Intra-procedural thrombosis<br>● Flow-limiting arterial dissection<br>● Distal embolization (worsening of symptoms or rendering further intervention impossible) |
| Alternative Interventions | ● Conservative management (lifestyle modification; supervised exercise programs)<br>● Surgical revascularization (endarterectomy; bypass) |
| Equipment | ● Angio pack<br>● Equipment for vascular access<br>● Heparin<br>● Catheter and sheath<br>● Wires for lesion crossing and for angioplasty<br>● Balloon catheters for angioplasty / pressure inflator<br>● Stents / drug-coated balloons<br>● Equipment for management of complications (stents, aspiration catheters) |
| Aftercare | ● Patient should remain supine until hemostasis has been confirmed |

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| Special considerations | • Diagnostic imaging prior to procedure will allow treatment planning<br>• Intra-procedural angiography shows a higher level of detail than non-invasive imaging<br>• Intra-procedural complications may be managed with prolonged balloon inflation, stent insertion, aspiration thrombectomy |
| References | • CIRSE standards of practice for thrombolysis in SFA/PA intervention: https://link.springer.com/content/pdf/10.1007%2Fs00270-014-0876-3.pdf |

| 6.6 Venography/venoplasty/stenting | |
|---|---|
| Indications | • Symptomatic superior vena cava (SVC) obstruction<br>• Recurrent subclavian vein stenoses in patients with Paget Schroeder or thoracic outlet syndrome post surgery<br>• Iliofemoral vein/inferior vena cava obstructions (including May Thurner)<br>• Filter related occlusion or stenosis<br>• Hemodialysis access-related venous stenoses<br>• Budd-Chiari syndrome<br>• Portal vein stenoses or occlusions |
| Contraindications | • Absolute – Active infection<br>• Relative – Coagulopathy (Plt <50k) |
| Procedure specific risks | • Bleeding<br>• Infection<br>• Thrombosis<br>• Vein rupture |
| Alternative Interventions | • Conservative management<br>• Surgery |
| Equipment | • Equipment for venous access including local anesthesia and ultrasound<br>• Procedure pack<br>• 6-8 Fr introducer sheath, 4-5 Fr diagnostic and selective catheter; guidewires |

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| | • Support catheters<br>• High pressure angioplasty balloons<br>• Bare metal stents (WallStents, Nitinol SE stents) |
| Aftercare | • Patients can be discharged home the same day after venous balloon angioplasty or stenting.<br>• Anticoagulation with possible antiplatelet agents.<br>• Follow-up with duplex Doppler ultrasound evaluation to assess patency. |
| Special considerations | • Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients.<br>• Can stent if stenosis refractory to prolonged venoplasty<br>• Crossing occlusions can be performed using advanced techniques (sharp recanalization, RF wire) |
| References | • Kandarpa, Krishna, et al. Handbook of Interventional Radiologic Procedures, Wolters Kluwer Health, 2016. ProQuest Ebook Central, https://ebookcentral-proquest-com.eresources.mssm.edu/lib/icahn-mssm/detail.action?docID=4931416. |

| **6.7 Venous Ablation** | |
|---|---|
| Indications | • Failure of conservative therapy<br>• Symptomatic Chronic venous insufficiency (CVI) of the superficial venous system: painful varicosities, edema, skin discoloration, bleeding, ulcers. |
| Relative Contraindications | • Significant or active deep venous thrombosis (DVT)<br>• Non-palpable pedal pulses<br>• Inability to ambulate, multiple significant co-morbidities<br>• Women who are pregnant or nursing<br>• Non-traversable vein segments (tortuous or occluded) |
| Procedure specific risks | • DVT<br>• Bruising<br>• Superficial phlebitis |

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|---|---|
| | • Skin injury<br>• Paresthesias |
| Equipment | ● Procedure Pack<br>● Ultrasound Guidance/sterile ultrasound cover<br>● Sterile bowls<br>● Normal saline<br>● 1% lidocaine<br>● Dilute tumescent anesthesia<br>● 25 G needle to administer tumescence<br>● Graduated support stockings: 20-30 or 30-40 mmHg<br>● Laser or RFA energy source |
| Technique | ● Use CEAP and VCSS classification systems to assess degree of disease initially and after treatment<br>● Ultrasound evaluation of chronic venous insufficiency<br>● Ultrasound access of GSV/SSV<br>● Perivenous tumescent anesthesia<br>● Ablation with Endovenous Laser Ablation (EVLA) or Radiofrequency Ablation (RFA)<br>● Stab phlebectomy at the time of ablation vs sclerotherapy of varicose veins in a later session |
| Aftercare | ● Compression required post treatment with compression stockings (at least 20-30 mmHg) for at least two weeks.<br>● Encourage ambulation post treatment<br>● Follow up at 1 week to evaluate patency of saphenofemoral junction/popliteal femoral junction<br>● Follow up ultrasound at 4 – 6 weeks to document successful closure |
| Special considerations | ● Oral benzodiazepines (Ativan 0.5 – 1 mg PO) can be considered just prior to procedure |
| Alternatives | ● Conservative Therapy: compression, anti-inflammatory medication, elevation<br>● Sclerotherapy<br>● Surgical ligation/stripping |

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| References | • Hardman RL, Rochon PJ. Role of interventional radiologists in the management of lower extremity venous insufficiency. Semin Intervent Radiol 2013;30:388-393.<br>• Min RJ, Khilnani NM (2014). Great Saphenous Vein Ablation in Mauro MA, Murphy KP, Thomson KR, Venbrux AC, Morgan RA, editors. *Image-Guided Interventions* (pp 796-800). Philadelphia, PA: Elsevier<br>• Darcy MD (2014). Ambulatory Phlebectomy in Mauro MA, Murphy KP, Thomson KR, Venbrux AC, Morgan RA, editors. *Image-Guided Interventions* (pp 790-795). Philadelphia, PA: Elsevier<br>• ACR Appropriateness Criteria: https://acsearch.acr.org/docs/69507/Narrative/ |

| 6.8 Dialysis access intervention | |
|---|---|
| Indications | • Venography for delineation of anatomy for access planning<br>• Malfunctioning but patent dialysis access<br>• Thrombosis of dialysis access<br>• Arterial or venous symptoms in a patient with dialysis access (eg. limb swelling, arterial insufficiency or steal phenomenon) |
| Contraindications | • Absolute – infected fistula<br>• Relative – uncorrectable coagulopathy |
| Procedure specific risks | • Distal embolization<br>• Dissection of fistula<br>• Venous rupture<br>• Pulmonary embolus |
| Alternative Interventions | • Conservative management<br>• Surgery |
| Equipment | • Equipment for venous access including local anesthesia and ultrasound<br>• Procedure pack<br>• 6-8 Fr introducer sheath, 4-5 Fr diagnostic and selective catheter; guidewires<br>• Support catheters |

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| | ● High pressure angioplasty balloons<br>● Covered stent in case of uncontrollable cephalic arch/subclavian vein rupture |
| Aftercare | ● Patients can be discharged home the same day after dialysis access intervention<br>● Anticoagulation with possible antiplatelet agents.<br>● Follow-up with duplex Doppler ultrasound evaluation to assess patency. |
| Special considerations | ● Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients.<br>● Can stent if stenosis refractory to prolonged venoplasty<br>● Crossing occlusions can be performed using advanced techniques (sharp recanalization) |
| References | ● Complications in Percutaneous Dialysis Interventions: How to Avoid Them, and How to Treat Them When They do Occur. Friedman T, Lopez EE, Quencer KB. Tech Vasc Interv Radiol. 2017 Mar; 20(1):58-64.<br>● Vascular and interventional radiology, the requisites 2e. Kaufman JA, Lee MJ. Pub Elsevier. |

| **6.9 Stroke intervention** | |
|---|---|
| Indications | ● Acute embolic stroke with large vessel occlusion and salvageable brain parenchyma |
| Contraindications | ● Absolute – no access to intracranial circulation<br>● Relative – established infarct |
| Procedure specific risks | ● Intra-procedural thrombosis<br>● Arterial dissection<br>● Clot fragmentation / distal embolization (worsening of symptoms or rendering further intervention impossible)<br>● Guidewire/catheter perforation resulting in subarachnoid hemorrhage |

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| Alternative Interventions | • Conservative management |
| Equipment | • Procedure pack<br>• 8/9F sheath, guide catheter, distal access catheter, microcatheter and microguidewire<br>• Heparin<br>• Thrombectomy device (stent-retriever; aspiration catheter and syringes) |
| Aftercare | • Patient should remain supine until hemostasis has been confirmed |
| Special considerations | • Perfusion imaging (eg CTP or DWI MR) and cross sectional angiography should be performed prior to procedure to determine patients for treatment and ascertain patency of carotid arteries |
| References | • Intervention for acute ischaemic stroke: https://ac.els-cdn.com/S0735109716325943/1-s2.0-S0735109716325943-main.pdf?_tid=42811e85-3fda-4937-ad86-cf32ffb2e363&acdnat=1546687204_9ea6916d1370c16610d52982211be7b2 |

| **6.10 Carotid artery stenting** | |
|---|---|
| Indications | • Under debate<br>• Significant carotid stenosis in acute embolic stroke<br>• Carotid blowout |
| Contraindications | • Relative – unstable patient, disease more appropriate for surgical management, uncorrectable coagulopathy |

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| Procedure specific risks | ● Intra-procedural thrombosis<br>● Flow-limiting arterial dissection<br>● Distal embolization (worsening of symptoms or rendering further intervention impossible) |
| Alternative Interventions | ● Conservative management (lifestyle modification; supervised exercise programs)<br>● Surgical revascularization (endarterectomy) |
| Equipment | ● Angio pack<br>● Equipment for vascular access<br>● Heparin<br>● Catheter and sheath<br>● Wires for lesion crossing and for angioplasty<br>● Balloon catheters for angioplasty / pressure inflator<br>● Stents / drug-coated balloons<br>● Equipment for management of complications (stents, aspiration catheters) |
| Aftercare | ● Patient should remain supine until hemostasis has been confirmed |
| Special considerations | ● Diagnostic imaging prior to procedure will allow treatment planning<br>● Intra-procedural angiography shows a higher level of detail than non-invasive imaging<br>● Intra-procedural complications may be managed with prolonged balloon inflation, stent insertion, thrombectomy<br>● The use of distal embolic protection may be considered |

| **6.11 Transjugular Intrahepatic Portosystemic Shunt (TIPS)** | |
|---|---|
| Indications | • Uncontrolled variceal hemorrhage<br>• Refractory ascites<br>• Hepatic hydrothorax<br>• Budd-Chiari<br>• Portal hypertensive gastropathy<br>• Hepatopulmonary Syndrome<br>• Hepatorenal syndrome |

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| | • Decompression of portosystemic collaterals prior to abdominal surgical procedures |
| Relative Contraindications | • Cardiac Failure, elevated right sided heart pressure and pulmonary hypertension<br>• Rapidly progressive liver failure<br>• Severe, uncorrectable coagulopathy<br>• Uncontrolled sepsis<br>• Unrelieved biliary obstruction<br>• Extensive primary or metastatic hepatic malignancy<br>• Clinically significant refractory encephalopathy |
| Procedure specific risks | Major complications:<br>• Bleeding and infarction<br>• Access vessel and hepatic arterial injury<br>• Stent Malposition<br>• Accelerated liver failure<br>• Encephalopathy<br>• Death<br><br>Minor complications:<br>• Fever<br>• Transient pulmonary edema<br>• Transcapsular puncture<br>• Damage to adjacent structures (bile duct, GB, kidney) |
| Equipment | • Procedure Pack<br>• Ultrasound and Fluoroscopy Guidance<br>• TIPS set: multiple commercial options<br>• 10 Fr Sheath, 5 Fr Catheters, various guidewires<br>• Marker Omni-flush/pigtail catheter to measure required length of stent<br>• $CO_2$ for wedged hepatic venogram/portal venogram<br>• Gore Viatorr Stent preferred over bare, self-expanding stents (improved patency) |

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| Technique | • Review prior imaging to assess anatomy<br>• Right IJ Access, 10 Fr sheath placement<br>• Hepatic vein access w 5 Fr catheter<br>• Wedged CO2 portal venogram<br>• Access portal vein using TIPS access set<br>• Measure pressure gradient<br>• Consider pre-dilation of parenchymal tract<br>• Deploy stent<br>• Completion venogram and final pressure measurements |
| Aftercare | • Typically admitted overnight for observation<br>• Clinical follow-up and ultrasound at 30 days and intermittently after that to assess TIPS patency.<br>• If stenosis identified on follow up ultrasound, TIPS revision can be considered. |
| Special considerations | • General Anesthesia<br>• Consider ascites drain placement at time of TIPS: this creates a more favorable angle between hepatic veins and IVC, and decreases hepatic mobility during transhepatic portal vein puncture |
| Alternatives | • DIPS: Direct Intrahepatic Portosystemic Shunt can be considered in cases of unfavorable anatomy: severe hepatic vein angulation/stenosis, Budd-Chiari, Polycystic Liver Disease.<br>• BRTO: Balloon-occluded Retrograde Transvenous Obliteration. Consider, particularly in the setting of gastric varices. |
| References | • https://www.acr.org/-/media/ACR/Files/Practice-Parameters/TIPS.pdf?la=en<br>• Keller S, Farsad K, Rosch J. The transjugular intrahepatic portosystemic shunt: technique and instruments. Tech Vasc Interventional Rad 2016;19:2-9<br>• Brooks MD, Li C. (2014). Transjugular Intrahepatic Portosystemic Shunts in Mauro MA, Murphy KP, Thomson KR, Venbrux AC, Morgan RA, editors. *Image-Guided Interventions* (pp 822-828). Philadelphia, PA: Elsevier. |

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| **6.13 Complex IVC filter retrieval** |

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| Indications | • Removal an IVC filter that was refractory to standard retrieval methods |
| Contraindications | • Absolute – anatomic consideration preventing safe removal |
| Procedure specific risks | • Injury (e.g. artery, IVC, nerve, viscera)<br>• Hematoma<br>• Filter fracture and embolization<br>• Infection |
| Alternative Interventions | • Leaving the IVC filter in place<br>• Surgery |
| Equipment | • Basic pack<br>• Vascular access equipment including local anesthesia<br>• Sheath/catheter to perform venography<br>• Filter retrieval devices (endobronchial forceps, wire loop, laser sheath, telescoping sheaths)<br>• Venous angioplasty balloons and stents as needed |
| Aftercare | • Patients rest in bed for 2 hours post procedure to reduce the risk of bleeding.<br>• Respiratory rate, blood pressure and heart rate should be monitored to allow any bleeding to be detected |
| Special considerations | • Fluoroscopy (dose, field size and screening time) should be kept to a minimum in all patients.<br>• Patients can remain on their anticoagulation for the procedure or heparized.<br>• Laser sheath assisted removal can be performed by introduction through large 16-20F sheath and activation according to safety guidelines. |
| References | • Kuyumcu, Gokhan, and T. Gregory Walker. "Inferior vena cava filter retrievals, standard and novel techniques." *Cardiovascular diagnosis and therapy* 6.6 (2016): 642.<br>• Kuo et al. Complex Retrieval of Fractured, Embedded, and Penetrating Inferior Vena Cava Filters: A Prospective Study with Histologic and Electron Microscopic Analysis. J Vasc Interv Radiol 2013; 24:622–630. |

## *Culture of safety*

Building and sustaining a culture of safety is imperative to the operation of an IR division. Broadly, a culture of safety is defined as “a culture that promotes an environment which is blame free, where there is no fear of punishment for reporting errors, wherein free collaboration between individuals of different ranks and disciplines to solve safety problems is encouraged, and where there is resource commitment to solving safety issues.” This is a multidisciplinary task which involves all members of the IR team, and it is every team member’s responsibility.

A culture of safety has been demonstrated to reduce preventable medical errors, which is especially important when establishing a new service with many potentially unfamiliar procedures, patient care scenarios, and staff needs. Errors are inevitable, but their likelihood can be reduced applying the following principles:

- Recognizing that errors are usually multifactorial and systemic
- Documenting, analyzing, and modifying practice when preventable mistakes occur
- Encouraging feedback from all team members
- Acknowledging the importance of defined leadership and delineated clinical roles
- Accepting the limitations of institutional hierarchy
- Avoiding blame or corrective action by punishment
- Facilitating administrative support for creation of institutional committees or bodies for studying and effecting necessary change

With respect to patient safety, specific practices may be implemented to decrease the risk of complications, minimize preventable errors, and improve outcomes. Observance of well-established universal safety protocols including the pre-procedural “time out” as well as procedural checklists should be established or, if already in place, reinforced. The WHO has provided a standardized safe surgery checklist, the use of which has been shown to improve outcomes and is associated with a reduced risk of major surgical complications [3].

Clear communication is one of the foundations of a culture of safety by promoting teamwork, streamlining activity in critical situations, and protecting patients through their assessment and treatment. Efforts should be made to standardize communication between team members, using practices such as “call-outs” and verbal confirmation of requests or orders. Special attention should be given to potential communication limitations such as language barriers, especially since English is the *lingua franca* of IR, which may not be as well understood at host sites.

Additionally, there are many principles of practice that can be introduced and sustained throughout an IR curriculum to help build a culture of safety:

- Emphasizing the importance of pre-procedural planning including available inventory
- Anticipation of complications and clinical contingency planning
- Favoring evidence-based approach to clinical decision making

- Fostering educational review of procedural complications or trainee errors through regular morbidity and mortality conferences (M&M)

As these protocols are not heavily dependent on material resources, they can be easily adapted to IR practice in developing nations.

Practical safety is also important for those teaching and learning IR. Many elements of a practical culture of safety for staff and operators are translatable from basic surgical education. For example, performance of proper sharps technique—identification, handling, and disposal of sharps—should be strictly observed and reinforced throughout IR training. Proper personal protective equipment (PPE) is necessary for a safe work environment, and should be a priority when considering site-specific resource limitations.

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3. WHO Safe surgery saves lives. Accessed at: http://www.who.int/patientsafety/safesurgery/faq_introduction/en/ 3rd May 2018.
4. European curriculum and syllabus for IR 2e. CIRSE Europe, February 2017.